

The University of Chicago

URINARY EXCRETION OF CITRIC ACID

I. EFFECT OF INGESTION OF LARGE AMOUNTS OF
ORANGE JUICE AND GRAPE JUICE

II. EFFECT OF INGESTION OF CITRIC ACID, SODIUM
CITRATE AND SODIUM BICARBONATE

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF HOME ECONOMICS

Year of Convocation
(1934)

By
CECILIA SCHUCK

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URINARY EXCRETION OF CITRIC ACID

I. EFFECT OF INGESTION OF LARGE AMOUNTS OF ORANGE JUICE AND GRAPE JUICE

CECILIA SCHUCK

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(Received for publication September 5, 1933)

Increase in the alkalinity of the urine and in organic acid excretion resulting from the ingestion of fruits or fruit juices has been reported by Blatherwick and Long ('22), McLaughlin and Blunt ('23), Chaney and Blunt ('25), Saywell ('32), Saywell and Lane ('33), and Clouse ('33). In general this increase in organic acid excretion when fruit juices are fed has been interpreted to mean that the ability of the body to oxidize the particular organic acids represented has been overstepped, with the consequent elimination of the excess in the urine. There is some evidence, however, that the organic acids eliminated in the urine are not remnants of unoxidized fruit acids, but that they are of metabolic origin. In this connection, Clouse cites the increase in uric acid excretion obtained by McLaughlin and Blunt ('23) on a diet high in fruits. Clouse ('33) found that the ingestion of large amounts of orange juice and grape juice likewise increase uric acid excretion.

Recently the functioning of organic acids as a part of the acid-base balance regulatory mechanism of the body has received considerable attention. Increase in the total organic acid output of the urine on administration of alkali in the form of sodium bicarbonate was noted by Fanconi ('28) and by Fasold ('30), which suggests that organic acid radicals of

metabolic origin furnish a means of freeing the body of excess base. The increased alkalinity produced by fruits and fruit juices might then account for the increased organic acid excretion observed when these are fed in large amounts.

Of the organic acids concerned in acid base balance regulation citric acid has received the most attention and is the one which at present is being most extensively investigated. Its occurrence in the urine was first demonstrated by Amberg and McClure ('17) who considered a direct food origin very improbable. Fasold ('30) concluded from one of his studies that a considerable part of the citric acid excreted is of food origin, but, at the same time, he suggests a connection of citric acid with an acid-base balance regulatory mechanism. In another study ('30) he presents additional evidence for the latter view, which is further supported by the work of Östberg ('31).

It then appears that the assumption that the excreted organic acids can be taken as a measure of the unutilized ingested organic acids is open to question. It was felt that this subject might profitably be further investigated by following a particular organic acid contained in fruit juices, determining in every case both the amount of the acid ingested and the amount excreted. In none of the fruit juice studies reported has this been done. Citric acid was chosen as the particular acid of investigation because of the interest in it as a component of an important class of fruits and as a probable metabolic product functioning in acid-base balance regulation. Orange juice and grape juice were selected because of the readily available data from their use in other studies on urinary acidity. Their great difference in citric acid content also commended them for the purpose of this study.

EXPERIMENTAL

Two separate studies were made, using four subjects for each study. The subjects were young graduate women of the nutrition department of The University of Chicago. Each study was divided into two 8-day periods. During the first

period, the subjects received a basal diet only. In the second period the basal diet was supplemented with 1000 cc. orange juice daily for one study, and for the other study, two of the subjects received 1000 cc. orange juice and two of them 1000 cc. grape juice daily. The subjects were kept on the basal diet for 3 days before collections and analyses were begun, and, likewise, a 3-day preliminary or adjustment period was allowed when the orange juice and grape juice additions were made. The analyses included determination of pH, titratable acidity, organic acids as a whole and citric acid.

The basal diet in the first study, which we shall designate diet A, consisted of the following: Apple sauce, 100 gm.; canned tomatoes, 100 gm.; thin cream, 5 tbs.; lean beef, 90 gm.; eggs, 90 gm.; head lettuce, 50 gm.; Irish potatoes, 150 gm.; cornflakes, 20 gm.; whole milk, $1\frac{1}{4}$ cups; canned peaches, 100 gm.; coffee, 1 to 2 cups; bread, butter, vanilla wafers, and salad oil in amounts to complete the caloric requirements of the different subjects. Diet B, which constituted the basal diet of the second study, differed in the following respects from diet A. The meat was reduced to 75 gm.; thick cream, $\frac{1}{2}$ cup, replaced the thin cream; the milk was omitted and shredded wheat biscuits (27 gm.) were used instead of cornflakes. Calculation of the potential acidity and alkalinity of the basal diets showed slight excess acidity (table 1). The addition of the fruit juices rendered the diets distinctly alkaline.

The caloric needs of all of the subjects while on the basal diet were evidently met, as was shown by the fact that weights remained constant, and in some instances the subjects showed small gains. The difference in caloric value between the basal diet and the basal diet with the fruit juice additions was, therefore, considered to be of no consequence in this study.

All food was weighed, prepared, and served in the laboratory, the subjects reporting for meals at 7:30, 12:30 and 6:30 each day. The orange juice was prepared from California oranges with an electric squeezer, so that it included a large part of the crushed pulp. The grape juice was a well-known commercial brand.

The collections of urine were made in clean wide mouth bottles with a sufficient layer of toluene to protect the urine from the air. At the end of the 24-hour period the specimens of each subject were thoroughly mixed and the volume recorded. The pH and titratable acidity were determined at once and organic acids within a few hours. The citric acid determination was begun within 24 hours, but the method involved steps requiring several days for completion.

TABLE 1

Acid base values of basal diets and fruit juice supplements (calculated from Sherman's figures)

FOOD	WEIGHT, GRAMS	APPROXIMATE POTENTIAL ACIDITY, CUBIC CENTIMETERS N ACID	APPROXIMATE POTENTIAL ALKALINITY, CUBIC CENTIMETERS N BASE
Apple sauce	100		2.0
Canned tomatoes	100		3.0
Lettuce	50		3.7
Potatoes	150		10.5
Canned peaches	100		3.0
Milk	300-0		7.11- 0
Lean beef	90-75	10.8- 9	
Eggs	90	9.9	
Cornflakes	20-0	2.0- 0	
Shredded wheat	0-27	0 - 3.3	
Bread (white)	125 (average)	8.0	
Vanilla wafers	40 (average)	2.5	
	Totals	33.2-32.7	29.3-22.4
Orange juice	928		41.66
Grape juice	800		31.2

Note. Where two figures are given those in the first column apply to diet A and those in the second column to diet B only. Calculations for butter, salad oil, and cream are omitted because figures for these could not be obtained.

The pH determinations were made colorimetrically, great care being taken to protect the samples from the air by covering with mineral oil, after carefully removing with a pipette from beneath the layer of toluene, with which the urine was kept covered at all times. Folin's method ('22) was used for the determination of titratable acidity; organic acids were titrated according to the method of Van Slyke and Palmer

('20) and, for citric acid, the pentabromacetone method, as modified by Amberg and McClure ('17) and McClure ('22), was employed. The results are given in tables 2 and 3.

The changes in urinary pH, titratable acidity and total organic acids produced by the orange juice and grape juice agree, in general, with results obtained by other workers.

There is a significant increase in citric acid excretion with both the orange juice and the grape juice. This increase is slightly greater with the orange juice, but the ratio of the amount excreted to the amount ingested is very much higher for the grape juice. With one subject, the increased excretion resulting from the grape juice actually exceeds by 20 per cent the amount of citric acid contained in the grape juice. It is evident from these results that citric acid must have a source other than that of the citric acid ingested.

The relation between the citric acid excreted and the total organic acids excreted is also of interest. There is no constancy in this relationship either on the basal diets or on the basal diets with the fruit juice supplements.

If the average citric acid increase for each subject for the 5-day period is compared with the average total organic acid increase produced by the orange juice, the former is approximately 40 to 60 per cent of the latter. With the grape juice, the citric acid increase represents 35 to 40 per cent of the total organic acid increase. It is evident, then, that organic acids other than citric account for a considerable portion of the increased organic acid output resulting from the ingestion of orange juice. Since the acid of orange juice appears (Hartman and Hillig, '30) to be practically 100 per cent citric acid the other acids must be formed in the utilization of the citric acid or have some other metabolic source. The increase in citric acid as compared with the increase in total organic acids produced by the grape juice is far too high to be explained on the basis of unutilized citric acid of the grape juice. It can only be accounted for as representing chiefly a metabolic product.

TABLE 2

Effect of orange juice on acid components of the urine

DAY	VOLUME, CUBIC CENTI- METERS	pH	0.1 N TITRATABLE ACIDITY, CUBIC CENTI- METERS	0.1 N ORGANIC ACIDS CUBIC CENTI- METERS	CITRIC ACID		VOLUME, CUBIC CENTI- METERS	pH	0.1 N TITRATABLE ACIDITY, CUBIC CENTI- METERS	0.1 N ORGANIC ACIDS CUBIC CENTI- METERS	CITRIC ACID	
					Grams	Cubic centimeters 0.1 N acid					Grams	Cubic centimeters 0.1 N acid
Subject B.												
Adjustment period—no analyses.												
1	1390	5.8	264	556		..	1380	5.9	280	717		...
2	1200	5.5	375	489	0.403	63	1400	6.0	269	806	0.664	104
3	900	5.6	278	413	0.307	48	1080	5.7	287	496	0.427	67
4	790	6.0	224	349	0.426	66	690	5.5	285	416	0.510	79
5	420	5.4	325	368	0.310	48	515	5.4	323	406	0.474	74
6	Aver.	5.6	293	435	0.361	56	Aver.	5.7	288	568	0.527	82
Subject S.												
Adjustment period—no analyses.												
1	1390	5.8	264	556		..	1380	5.9	280	717		...
2	1200	5.5	375	489	0.403	63	1400	6.0	269	806	0.664	104
3	900	5.6	278	413	0.307	48	1080	5.7	287	496	0.427	67
4	790	6.0	224	349	0.426	66	690	5.5	285	416	0.510	79
5	420	5.4	325	368	0.310	48	515	5.4	323	406	0.474	74
6	Aver.	5.6	293	435	0.361	56	Aver.	5.7	288	568	0.527	82
Subject K.												
Adjustment period—no analyses.												
1	1940	6.5	148	626	0.853	133	1990	6.1	251	692		...
2	1700	6.8	147	487	1.044	163	2920	6.5	215	685	2.102	330
3	1640	6.8	153	681	1.017	159	2360	6.6	185	849	1.746	272
4	1500	6.8	137	585	0.925	144	2430	6.0	201	699	1.749	272
5	1410	6.8	147	663	0.937	146	2340	6.3	234	907	1.688	264
6	Aver.	6.7	146	608	0.962	150	Aver.	6.3	217	746	1.821	284
Subject R.												
Adjustment period—no analyses.												
1	1500	5.4	240	444	0.463	72	1515	5.5	262	469	0.424	66
2	1635	5.4	304	444	0.478	74	2230	5.9	238	474	0.570	89
3	2350	5.5	363	605	0.796	124	1400	5.6	218	418	0.489	76
4	1650	5.4	308	505	0.702	109	1400	5.6	298	408	0.325	51
5	1895	6.2	198	522	0.817	127						
6	Aver.	5.5	304	522	0.817	127						

Basal diet B plus 1000 cc. orange juice	1	Adjustment period—no analyses.						Adjustment period—no analyses.					
	2												
	3												
	4	1830	6.7	190	609	0.929	145	1395	6.6	124	649	0.552	86
	5	2000	6.5	138	674	1.242	194	1420	6.6	186	513	0.631	106
	6	1590	6.3	240	604	1.381	216	1900	6.3	194	518	0.895	140
	7	1605	6.7	171	614	1.068	167	1519	6.6	159	475	0.617	96
	8	1720	6.0	241	626	0.975	152	Aver.	6.5	165	536	0.686	107
Subject M.H.													
Basal diet A	1							Subject C.S.					
	2												
	3	Adjustment period—no analyses.						Adjustment period—no analyses.					
	4	2050	6.2	232	508	0.648	101	1600	5.8	209	512	0.437	67
	5	1350	6.0	283	489	0.451	70	950	5.8	219	478	0.472	74
	6	1350	5.8	253	540	0.541	84	740	5.6	269	482	0.537	84
	7	1560	5.6	306	507	0.748	115	590	5.6	298	424	0.482	75
	8	720	5.4	267	430	0.597	93	420	5.6	212	436	0.482	75
Subject C.S.													
Basal diet A plus 1000 cc. orange juice	1	Adjustment period—no analyses.						Adjustment period—no analyses.					
	2												
	3												
	4	1560	6.5	139	586	0.837	131	1920	6.9	125	660	0.806	126
	5	1610	6.9	108	624	1.027	160	2010	6.8	178	503	0.924	144
	6	2080	6.8	153	648	0.971	151	2360	6.8	144	566	0.944	147
	7	1570	6.9	136	496	0.996	155	1780	6.8	139	552	0.925	144
	8	1790	6.9	132	684	0.956	149	1700	6.8	170	653	0.816	127
Subject C.S.													
Basal diet A plus 1000 cc. orange juice	1	Adjustment period—no analyses.						Adjustment period—no analyses.					
	2												
	3												
	4	1560	6.5	139	586	0.837	131	1920	6.9	125	660	0.806	126
	5	1610	6.9	108	624	1.027	160	2010	6.8	178	503	0.924	144

TABLE 3
Effect of grape juice on acid components of urine

	DAY	VOLUME, CUBIC CENTI- METERS	pH	0.1 N TITRATABLE ACIDITY, CUBIC CENTI- METERS	0.1 N ORGANIC ACIDS CUBIC CENTI- METERS	CITRIC ACID							
						Grams	Cubic centimeters 0.1 N acid						
Basal diet B	1	Subject C.					Subject H.						
	2												
	3												
	4	1170	5.5	323	531	0.721	112	1500	5.4	246	454	0.623	97
	5	1790	5.5	294	494	0.755	121	2065	6.4	166	450	0.584	91
	6	1780	5.5	332	536	0.930	145	2080	6.1	201	453	0.671	105
	7	1695	5.9	282	528	1.033	161	1545	5.9	216	424	0.546	85
	8	1690	6.1	210	538	0.917	143	1645	6.3	160	452	0.748	117
		Aver.	5.7	288	525	0.871	134	Aver.	6.0	197	446	0.634	99
	Basal diet B plus grape juice	1	Adjustment period—no analyses.					Adjustment period—no analyses.					
2													
3													
4		1699	5.6	320	552	0.982	137	1920	6.8	175	556	1.001	156
5		1820	6.3	202	621	1.164	182	1655	6.1	195	573	0.900	140
6		1740	5.8	270	576	1.083	170	1435	6.1	207	524	0.866	135
7		1665	6.3	218	611	0.980	153	1500	6.3	206	540	0.895	141
8		1770	6.0	236	618	0.934	146	1705	6.3	196	548	0.886	138
		Aver.	6.0	258	595	1.019	159	Aver.	6.3	195	548	0.909	141

Note: The figures for pH titratable acidity and organic acids for subjects R., K., C. and H. are the results of analyses made by students in a problem course. They are used by courtesy of Mrs. Ruth Cowan Clouse, who conducted the course.

TABLE 4

Citric acid ingested and excreted as a result of adding orange juice and grape juice to the basal diet

SUBJECT	B.	S.	M.H.	C.S.	K.	R.	O.	H.
Average citric acid excretion on basal diet. Grams	0.361	0.527	0.597	0.482	0.452	0.658	0.871	0.634
Average citric acid excretion on basal diet + 1000 cc. orange juice. Grams	0.962	1.821	0.956	0.883	0.686	1.115		
Average citric acid excretion on basal diet + 1000 cc. grape juice. Grams							1.019	0.909
Average increase in citric acid excretion. Grams	0.601	1.294	0.359	0.401	0.234	0.457	0.148	0.275
Amount of citric acid ingested in 1000 cc. orange juice. Grams	7.95	7.95	7.95	7.95	8.51	8.51		
Amount of citric acid ingested in 1000 cc. grape juice. Grams							0.23 ¹	0.23 ¹
Increased excretion in terms of per cent of amount ingested	7.5	16.6	4.5	5.3	2.6	5.3	64	120

¹ Based on average figures reported in J. Assoc. Official Agr. Chem., 1930, 13, 99.

A very small part of the increase in total organic acids with both the orange juice and grape juice is due to uric acid according to the findings of Clouse previously cited. Determination of other acids concerned in this increase must await the development of new methods now being investigated for use in the study of urinary acidity.

SUMMARY

Two studies made with eight women subjects on the effect of orange juice and grape juice on the urinary excretion of citric acid are reported. The effect on urinary pH, titratable acidity, and excretion of total organic acids was also observed.

The following results were obtained when 1000 cc. orange juice or 1000 cc. grape juice were added to a basal diet.

1. The pH was increased and the titratable acidity was decreased. Organic acid excretion as a whole was increased. These results confirm those obtained by other workers.

2. Citric acid excretion was increased. The increase produced by the orange juice was slightly greater than that produced by the grape juice, but the ratio of the amount of citric acid excreted to the amount ingested was very much higher for the grape juice. With one subject, the increase represented 20 per cent more than the citric acid contained in the grape juice. The latter result indicates a metabolic source of citric acid.

3. The increase in citric acid with the orange juice represented only 40 to 60 per cent of the total organic acid increase. Other organic acids must have been formed in the body.

4. Thirty-five to 40 per cent of the total organic acid increase with the grape juice was due to citric acid. Only a very small part of this could have come from the citric acid of the grape juice, and therefore, most of it can be accounted for only on the basis of having a metabolic origin.

The organic acids representing products of metabolism may arise as a result of the alkalizing effect of the fruit juices.

The author wishes to express her appreciation of the interest and advice of Mrs. Ruth Cowan Clouse at whose suggestion this study was begun. The hearty cooperation of the young women serving as subjects is gratefully acknowledged.

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URINARY EXCRETION OF CITRIC ACID

II. EFFECT OF INGESTION OF CITRIC ACID, SODIUM CITRATE AND SODIUM BICARBONATE

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In a previous paper (Schuck, '34) the increased output of citric acid when orange juice and grape juice supplements were added to a basal diet was reported. As a result of this study it was decided to investigate the influence of pure crystalline citric acid, sodium citrate and sodium bicarbonate upon citric acid excretion in order to obtain further information on: 1) The effect of an increased citric acid intake. 2) The effect of increased alkalinity together with increased citrate ion ingestion. 3) The effect of merely increasing alkalinity.

At the time this study was begun there were with the exception of the work of Gonce and Templeton ('30) no published reports on the effect on citric acid excretion of feeding citric acid to humans. And so far as the author was able to determine, the effect of sodium citrate on citric acid excretion had not previously been studied with humans.

Gonce and Templeton ('30) investigated the citric acid excretion of four normal children 7 to 12 years of age. They fed a basal diet for 2 days, and then supplemented the basal diet with dehydrated citric acid for a period of 3 days. The citric acid was fed at a level of 4 gm. per 15 pounds of body weight, with a range of 11 to 13 gm. daily for the different children. They found that the citric acid supplement did not result in increased citric acid excretion.

A number of studies have been reported on the effect of the administration of sodium bicarbonate on total organic acid excretion and on the excretion of certain specific organic acids, including citric. Fanconi ('28) observed that the organic acid excretion on a vegetable diet, which was already high, could be further increased by the addition of sodium bicarbonate or the potassium salt of another organic acid. Goiffon ('25, '28) observed increased excretion of citric acid on doses of sodium bicarbonate of from 5 to 15 gm. McCleod and Knapp ('18) found that lactic acid output was increased by the ingestion of sodium bicarbonate. Fasold ('30) in a study on a 10-year-old boy, in which he determined total organic acids, volatile acids, hippuric and citric acid, found that the total organic acids, hippuric and citric acid, were all higher on a vegetable than on a meat diet. When he further increased the alkalinity of the urine by adding sodium bicarbonate to the vegetable diet, the latter constituents were further increased. Östberg ('30) at about the same time, reported increased citric acid elimination resulting from administration of sodium bicarbonate. He found that there was a close correlation between citric acid excretion and ammonia excretion. With a decrease in citric acid, there was an increase in ammonia, and vice versa. As a result, he concluded that citric acid plays at least a small part in acid-base balance regulation.

In a later study Östberg ('31) reports an investigation of the effect of citric acid, sodium citrate, sodium bicarbonate, hydrochloric acid, ammonium chloride, calcium chloride, and a low carbohydrate to fat ratio on citric acid excretion. He found that with citric acid doses of from 10 to 15 gm., there was greatly increased output in one case, and in another case a decrease. Thirty grams showed in one case an increase from 0.78 to 1.5 gm., and in another only a small increase. Thirty to 40 gm. gave for one subject in periods of 2 or 3 days a slightly decreased output, accompanied by a decrease in pH and increase in ammonia. This variability in effect led to the conclusion that in cases in which citric acid influences

the acid-base balance, its administration brings about a decreased output, and in cases where there is no effect on the acid-base balance, administration of citric acid may increase its excretion. Östberg ('31) found that increased alkalinity due to ingestion of either sodium citrate or sodium bicarbonate gave increased excretion of citric acid.

Boothby and Adams ('32) have confirmed Östberg's results with sodium bicarbonate, but they feel that the significance of citric acid as a factor in acid-base balance regulation is still questionable. They point out in this connection that it is possible to have an acid urine containing large amounts of organic acids with the normal amount of citric acid. Süllman and Shearer ('32) obtained an increase in citric acid excretion with both sodium carbonate and sodium citrate, but when both were administered at the same time the figure was not significantly different from that obtained when either was used alone.

EXPERIMENTAL

The subjects for this study were six young graduate women of the nutrition department of The University of Chicago. Four of these, B., M.H., S. and C.S., were the same as those serving in the study previously reported (Schuck, '34), and the basal diet for this group was diet A, the composition of which has already been given. The basal diet for the two new subjects, M. and V., which we shall designate diet C, consisted of the following: apple sauce, 100 gm.; cornflakes, 20 gm.; American cheese, 30 gm.; head lettuce, 100 gm.; canned tomatoes, 100 gm.; potatoes, 150 gm.; ground lean steak, 90 gm.; canned peaches, 100 gm.; whole milk, $1\frac{1}{2}$ cups; thin cream, $\frac{1}{4}$ cup; bread, butter and vanilla wafers in amounts to complete the caloric requirements of the different subjects.

The weights of the subjects were followed as before, and their constancy indicated that caloric needs were met throughout the experiment.

The supplements used were citric acids, 12 gm. daily, a chemically equivalent amount of sodium citrate, and sodium

bicarbonate, 10 gm. daily. The citric acid was administered to all six subjects, the sodium citrate to B., M.H., S. and C.S., and the sodium bicarbonate to C.S., M. and V. An 8-day period was allowed for each supplement, the first 3 serving as preliminary days, during which the subject might become adjusted to the new substance. Collections and analyses were made during the remaining 5 days of the period.

The supplements were dissolved in water and the daily amounts were consumed in three separate doses through the day. The citric acid was diluted and sweetened to make a palatable and pleasing beverage, but palatability could not be attained with the other supplements.

Urine collections and analyses were made as described in an earlier study (Schuck, '34). The results are given in tables 1 and 2.

It is apparent that the ingestion of citric acid had little or no effect on the pH of the urine. In most cases, there was a slight decrease in titratable acidity and a decrease in the total organic acid excretion. The citric acid output was decreased in some instances and increased in others. As can readily be seen, there was no parallelism between the total organic acid excretion, as measured by the Van Slyke Palmer method, and the citric acid excretion—a finding which is in agreement with observations made by Östberg ('31).

The sodium citrate gave in every case a marked increase in pH, a marked decrease in titratable acidity, and a large increase in the total organic acids and citric acid excretion. The total organic acids and citric acid amounted to two or three times the excretion on the basal diet. The effect on pH and citric acid excretion produced by the sodium citrate is in general agreement with the results obtained by Östberg ('31). He fed sodium citrate at lower levels, so that the change in pH was not so great, and correspondingly the increase in citric acid excretion was less.

The effect of the sodium bicarbonate on the pH, titratable acidity and citric acid was similar to that of the sodium citrate, in that there was a significant increase in the pH and

TABLE 1

Effect of citric acid and sodium citrate on acid components of the urine

	DAY	Subject B.						Subject M.H.					
		VOLUME, CUBIC CENTI- METERS		pH	0.1 N TITRATABLE ACIDITY, CUBIC CENTI- METERS		0.1 N ORGANIC ACIDS CUBIC CENTI- METERS		CITRIC ACID		CITRIC ACID		
		Grams	Cubic centimeters		Grams	Cubic centimeters	Grams	Cubic centimeters	Grams	Cubic centimeters			
Basal diet A	1	Adjustment period—no analyses.											
	2												
	3												
	4	1390	5.8	264	556	...	..	2050	6.2	232	508		...
	5	1200	5.5	375	489	0.403	63	1350	6.0	283	489	0.648	101
	6	900	5.6	278	413	0.307	48	1350	5.8	253	540	0.451	70
	7	790	6.0	224	349	0.426	65	1560	5.6	306	507	0.541	84
	8	420	5.4	325	368	0.310	48	720	5.4	267	430	0.748	117
		Aver.	5.6	293	435	0.361	56	Aver.	5.8	268	495	0.597	93
	Adjustment period—no analyses.												
Basal diet + citric acid	1	Adjustment period—no analyses.											
	2												
	3												
	4	1190	5.9	140	339	0.547	84	1920	6.0	242	443	0.576	90
	5	960	6.0	230	345	0.555	87	1670	6.3	189	467	0.481	75
	6	770	5.6	263	385	0.622	97	1650	6.5	86	470	0.462	72
	7	680	5.4	296	467	0.598	93	830	5.7	224	492	0.481	75
	8	560	5.7	192	348	0.560	87	1280	6.2	184	501	0.512	80
		Aver.	5.7	244	376	0.576	90	Aver.	6.1	181	474	0.502	78
	Adjustment period—no analyses.												
Basal diet + Na citrate	1	Adjustment period—no analyses.											
	2												
	3												
	4	950	8.3	41	1001	1.243	194	1940	8.2	21	682	1.058	165
	5	1280	8.4	45	1303	1.321	206	1690	8.5	44	1365	1.418	221
	6	1550	8.3	121	867		...	1370	8.4	125	1274	1.507	250
	7	1560	8.2	162	1009	1.094	171	1640	8.3	214	1567	1.501	234
	8	1540	8.2	194	1134	1.212	189	1600	8.2	150	1867	1.984	325
		Aver.	8.2	112	1262	1.217	190	Aver.	8.3	110	1557	1.489	231
	Adjustment period—no analyses.												

TABLE 2

Effect of citric acid, sodium citrate and sodium bicarbonate on acid components of the urine

	DAY	VOLUME, CUBIC CENTI- METERS	pH	0.1 N TITRATABLE ACIDITY, CUBIC CENTI- METERS	0.1 N ORGANIC ACIDS CUBIC CENTI- METERS	CITRIC ACID	
						Grams	Cubic centimeters
Subject S.							
Basal diet A	1	Adjustment period—no analyses.					
	2						
	3						
	4	1380	5.9	280	717	...	...
	5	1400	6.0	269	806	0.664	104
	6	1080	5.7	287	496	0.427	67
	7	690	5.5	285	416	0.510	79
	8	515	5.4	326	406	0.474	74
		Aver.	5.7	288	568	0.527	82
		1					
Basal diet + citric acid	2	Adjustment period—no analyses.					
	3						
	4	2000	5.7	288	400	0.760	119
	5	1900	5.6	306	474	0.836	130
	6	1340	5.6	344	573	1.018	160
	7	1980	5.7	292	583	1.029	161
	8	2300	5.4	361	753	1.204	188
		Aver.	5.6	318	556	0.969	151
		1					
	Basal diet + Na citrate	2	Adjustment period—no analyses.				
3							
4		2070	8.1	62	1275	2.260	353
5		1450	8.3	55	1352	2.146	335
6		2400	8.2	190	1017	2.640	412
7		2120	8.0	177	768	1.888	295
8		9200	8.1	940	1618	2.300	357
		Aver.	8.2	188	999	1.535	240

	4	960	7.8	106	1034	1.234	193
	5	1850	7.8	103	576	1.461	226
	6	2340	7.8	111	376	1.380	215
	7	1250	8.2	20	270	0.767	120
	8	1810	8.2	65	660	1.309	204
	Aver.		7.9	81	581	1.230	192
Subject V.							
	1	Adjustment period—no analyses.					
	2						
	3						
	4	3810	6.4	217	504	0.521	81
	5	3200	6.0	293	450	0.732	114
	6	4260	6.6	195	494	0.592	92
	7	4130	6.4	199	582	1.110	173
	8	4130	6.4	183	560	0.689	107
	Aver.		6.3	217	518	0.728	114
Adjustment period—no analyses.							
	1						
	2						
	3						
	4	3860	5.6	252	248	0.984	153
	5	4880	6.4	191	358	0.685	107
	6	5860	6.4	185	578	0.808	126
	7	4810	6.2	268	530	0.550	86
	8	4200	6.5	184	556	0.835	130
	Aver.		6.2	216	454	0.772	120
Adjustment period—no analyses.							
	1						
	2						
	3						
	4	6510	7.3	155	484	0.856	133
	5	5440	7.4	194	500	1.115	174
	6	6550	7.4	221	704	1.506	234
	7	6170	7.4	159	460	0.734	114
	8	5910	7.4	141	538	1.229	192
	Aver.		7.4	174	537	1.088	177

citric acid excretion and a decrease in titratable acidity. The excretion of total organic acids did not show a significant change with two of the subjects. One subject, however, showed an appreciable increase in total organic acid excretion. This is in agreement with the observations of other workers (Fanconi, '28; Goiffon, '25; and Fasold, '30).

The difference in effect upon citric acid excretions of feeding citric acid and sodium citrate in chemically equivalent amounts might be explained on the ground that the former is more completely utilized by the body, and that therefore there exists much less likelihood of any of it being excreted when fed in large amounts. Attention should be called to the fact, as having some possible bearing on the question, that the subjects while on the sodium citrate supplement experienced a feeling of nausea, malaise, and in some instances there was a marked diarrhea. The fact, however, that there was little change in the pH of the urine with the administration of citric acid, but that with the sodium citrate there was a marked increase in pH is significant in light of the theory that increased alkalinity is accompanied by increased citric acid excretion. The increase in citric acid output produced by administration of sodium bicarbonate is further evidence for the belief that citric acid is, at least, one of the important organic acids concerned with the elimination of excess base. The smaller sodium bicarbonate dosage used in this study did not bring about as great an increase in pH as was obtained with the sodium citrate, and there was also a smaller increase in the citric acid output. The pH and the citric acid increase, however, closely approach that obtained with the sodium citrate, while the effect upon total organic acid output is considerably less. The meaning of this is not clear.

The results of this investigation give increased evidence for the theory that citric acid excretion is influenced principally by changes in alkalinity, and not by the citric acid intake. They appear to strengthen the view that citric acid is one of the organic acids functioning in acid-base balance regulation.

SUMMARY

A study made with six women subjects of the effect of citric acid, sodium citrate and sodium bicarbonate on the urinary excretions of citric acid is here reported. The effect on urinary pH, titratable acidity, and excretion of total organic acids was also observed.

The following results were obtained with chemically equivalent amounts of citric acid and sodium citrate:

1. The citric acid produced little or no change in the pH of the urine; the sodium citrate brought about a marked increase.

2. The titratable acidity was slightly decreased as a result of the ingestion of citric acid, while the sodium citrate brought about a marked decrease.

3. Total organic acid excretion was decreased by the citric acid, but greatly increased by the sodium citrate.

4. Citric acid excretion was decreased in some cases and increased in others as a result of the citric acid ingestion while the sodium citrate brought about a marked increase in every case. The results here are in agreement with those obtained by Östberg.

5. The total organic acids and citric acid excreted as a result of the ingestion of sodium citrate amounted to two to three times the excretion on the basal diet.

The increase in pH and the decrease in titratable acidity brought about when sodium bicarbonate was fed were accompanied by a small increase in total organic acids and a considerable increase in citric acid excretion. Increase in total organic acid excretion on ingestion of sodium bicarbonate has been noted in the past, and, more recently, like observations have been made on citric acid excretion.

Apparently, citric acid excretion is not dependent upon citric acid ingestion.

Increased evidence is presented here for the view that citric acid is one of the organic acids which plays a part in acid-base balance regulation.

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